p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 3, Number 1, page 47 - 66, October 2019
*Accredited SINTA 2 by Ministry of Research, Technology, and Higher Education of The Republic of Indonesia No. 23/E/KPT/2019 on August 8th, 2019 from October 1st, 2018 to September 30th, 2023*

Indonesian Journal of
Urban and Environmental Technology
http://www.trijurnal.lemlit.trisakti.ac.id/index.php/urbanenvirotech
urbanenvirotech

# THE CURRENT STATUS AND STEPS TOWARDS SUSTAINABLE WASTE MANAGEMENT IN THE DEVELOPING COUNTRIES: A CASE STUDY OF PESHAWAR-PAKISTAN

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## ABSTRACT

**Aim:** This article was meant to review the current status and limitations of treating municipal solid waste (MSW) by the developing countries with a case study from Peshawar-Pakistan. **Methodology and Results:** The city is divided into 4 towns and used a stratified sampling and survey to inspect MSW management from collection to final disposal. The results show food contributes to 14.3% of the total waste, followed by plastic waste 4%, paper, 2.7%, glass 1.2%, wood 1.1%, and metals/rubber 0.6%. **Conclusion, significance, and impact study:** About 60% of the wastes at collection points make the air difficult for breathing. There are several treatment options for the sustainable management of MSW, including composting, incineration, gasification, pyrolysis, biological treatment, and recycling. The developed countries had strictly imposed regulations to increase waste recycling and material recovery. In contrast, in the developing countries, the lack of proper legislation, planning, and awareness regarding waste reduction has worsened the MSW related problems. In this article, the essential steps needed in formulating the strategy for sustainable MSW management and assessment in terms of sustainability in the developing countries have been considered.

## MANUSCRIPT HISTORY

- Received September 2019
- Revised September 2019
- Accepted September 2019
- Available online October 2019

## KEYWORDS

- Landfill
- Peshawar
- Recycling
- Solid waste
- Waste management

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 3, Number 1, page 47 - 66, October 2019
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## 1. INTRODUCTION

The rapid growth in population, conurbations and industrialization has resulted a significant generation of municipal solid waste (MSW) (Anjum *et al.,* 2016; Waqas *et al.,* 2019). The waste was not the major problem when the human population was low and nomadic however gradually increased with increasing the human activities for fulfilling the life demands (Giusti, 2009; Nizami *et al.,* 2017). Depending on the rate of urbanization, lifestyles and patterns of materials consumption each country generate different types of MSW with various composition (Eurostat, 2014). The produced waste as a result of anthropogenic activities are mostly disposed to landfills or dumpsites without any material recovery (Waqas *et al.,* 2018a). The improper waste management can led to various environmental issues including contamination of soil, air and water and public health problems such as cholera that was associated with contaminated water containing pathogens that adversely affect the European population in the 19th century. Moreover, the other direct consequences on public heath due to poor waste management can be observed especially in the developing countries of the world (Nizami *et al.,* 2017; Siami *et.al,* 2019*).*

The health and government authorities are under extreme pressure from the epidemiological evidences as a result of these activities on public health (Wilson *et al.,* 2015; Spoann *et al.,* 2018). The sustainable management of MSW has become a challenge to both developing and developed nations and trying to meet pressure from international and national communities to reduce their overall environmental impacts (Waqas *et al.,* 2018b; Widyarsana and Salmaa, 2019). However, the technological advancement over the time has organized and specialized the waste management practices. Currently, there are various treatment options classified as composting, incineration, biological treatment, recycling and landfilling (Waqas *et al.,* 2019). The developed countries are trying to increase the recycling and material recovery to avoid the waste going to landfill (Miandad *et al.,* 2019). The EU member states are strictly bound by directives to increase the recoverability of the waste through recycling and reduce the amount of waste to go to landfill (Allesch and Brunner, 2014). The EC directives of the landfill (99/31/EC) stated that according to 1995 waste level, the member states are liable to reduce the biodegradable waste to 35% to send to landfill. Similarly, the revised framework of the waste directive (2008/98/EC) requires 50% recycling of the household waste by 2020 (Allesch and Brunner, 2014).

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Similarly, in the developing countries there are still numerous problems in management of MSW. The most common are the lack of the proper waste collection (Allesch and Brunner, 2014; Waqas *et al.,* 2018b). However if collected, the waste are openly dumped in the outskirt of the city without any resource recovery (Waqas *et al.,* 2018a). Moreover, due to lack of knowledge regarding MSW management, waste reduction and awareness regarding contamination the lying areas are continuously filled with waste one after other that results in several public health and environmental consequences (Jha *et al.,* 2011). This paper investigate the current status of waste management practices in both the developed and developing countries with a case study from Peshawar-Pakistan. Moreover, various options for waste treatment, important steps along with different aspects for their assessment were discussed for achieving sustainable MSW management especially in the developing countries.

## 2. RESEARCH METHODOLOGY

### 2.1 Study Area

The area selected for the current investigation was Peshawar city which is the capital and largest city of Khyber-Pakhtunkhwa province of Pakistan. The total population of the city is about 3.7 million. The city is divided in to 4 towns and these towns have been included in the 4 zones. Moreover, there are 92 councils out of which 43 belongs to the urban areas whereas 49 belongs to the rural areas.

### 2.2 Waste Collection

Among the 4 towns, a stratified sampling method was used to identify various colonies on the basis of population. Using random sampling about 20 houses were selected from each colony. Plastic bags were given to each house for the waste collection. The waste was collected for 7 days on daily basis. After collection the waste was taken into quantification and characterization and the percent composition of each material such as organics, plastic, meat, glass, metals and wood products was estimated accordingly. Similarly, the estimated daily waste production was predicted on the basis of collected data.

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## 2.3 Field Survey

A survey was conducted to investigate the MSW management starting from collection to final disposal. Various collection points and dumping site were visited in the metropolitan area of Peshawar. The main dumping sites used for waste dumping are Hazar Khwani dumping site, LandiAkhoon Ahmad dumping site and Hayatabad dumping site.

# 3. RESULTS AND DISCUSSION

## 3.1 Production of MSW

For formulating the strategy regarding MSW management the developing countries usually depend on projected data of waste generation per capita based on survey (Dhokhikah and Trihadiningrum, 2012). Likewise, in the current study the total waste production in Peshawar city was predicted on the basis of the collected data obtained from the selected houses from different colonies from each town. The data in the Table 1 depicts the total waste generation and their percent composition in different areas of Peshawar city. Based on the obtained data it has been calculated that that daily waste production in Peshawar city reaches 650.8 tons. Correspondingly, the waste of all 4 towns are rich in organics predominantly of food waste that contributes 14.5, 13.5, 14.1 and 15.2% in town 1, 2, 3 and 4 respectively. Similar to plastic waste is the second largest waste stream fallowed by paper and glass. The overall data showed that food waste contributes 14.3% of the total waste fallowed by plastic waste (4%), paper (2.7%), glass (1.2%), wood (1.1%) and metals/rubber (0.6%) (Table 1). Furthermore, the generation of MSW is about 0.4 kg/day. The similar has also been reported by Sharholy *et al.*, (2008) who stated that in India it has been estimated that the produced waste in small, medium in big cities is about to 0.1, 0.4 and 0.5 kg/capita/day respectively. However, in developing countries the waste production in the high income cities and towns reaches above 1 kg/capita/day (World Bank 2010). According to World Bank report, the waste produced in 1998 - 1999 by the urban areas of Asian countries was above 760,000 tons/day which is projected to increase to 1.8 million tons/day by 2025 (Dhokhikah and Trihadiningrum, 2012). As these estimates are based on projected data hence the real figure might be double fold of this amount. As a result of huge amount of waste production, the pressure on landfills is continuously increasing which require a proper management strategy for material recycling and reuse (Table 2).

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**Table 1** Municipal solid waste production in Peshawar

| Peshawar city | Waste production (Tons/day) | Composition (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Food Waste | Plastic | Paper | Glass | Metals/ Rubber | Wood |
| Town 1 | 171.4 | 14.5 | 4.1 | 2.9 | 1.6 | 0.9 | 0.8 |
| Town 2 | 168.3 | 13.5 | 4.3 | 3.1 | 1.2 | 1.1 | 0.5 |
| Town 3 | 152.8 | 14.1 | 3.8 | 3.1 | 1.4 | -- | 1.1 |
| Town 4 | 158.3 | 15.2 | 3.8 | 1.8 | 0.8 | 0.5 | 2.1 |
| Total | 650.8 | | | | | | |
| Average | | 14.3 | 4.0 | 2.7 | 1.2 | 0.6 | 1.1 |

**Table 2** Production and composition of municipal solid waste in major Asian cities (Dhokhikah and Trihadiningrum, 2012)

| City | Waste production (Tons/day) | Composition (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Organics | Plastic | Paper | Glass | Metals | Rubber | Wood |
| Karachi (Pakistan) | 9,900 | 30 | 9.4 | 6.2 | 6.1 | 4.2 | 1.3 | 2.2 |
| K. Lumpur (Malaysia) | 3,799 | 61.5 | 15.3 | 16.5 | 1.2 | 0.25 | 0.6 | 0.4 |
| Jakarta (Indonesia) | 6,000 | 68.1 | 11.1 | 10.1 | 1.6 | 1.9 | 0.5 | -- |
| Bangkok (Thailand) | 8,778 | 42.7 | 10.8 | 12.1 | 6.6 | 3.5 | 2.6 | 6.9 |
| Kathmandu (Nepal) | 523 | 71 | 12 | 7.5 | 1.3 | 0.5 | 0.3 | -- |
| Dhaka (Bangladesh) | 5,340 | 68.3 | 4.3 | 10.7 | 0.7 | 2.0 | 1.4 | -- |
| Rasht (Iran) | 420 | 80.2 | 9 | 8.7 | 0.2 | 0.7 | -- | 0.4 |

## 3.2 Collection of MSW

The basic pillar for a sustainable MSW management is the collection efficiency. In Peshawar there is a poor collection and disposal of MSW. About 60% of the waste remain in streets or at collection points where it emits pollutants into the air and make it unacceptable for breathing. Currently, the Water & Sanitation Services Peshawar (WSSP) and Municipal Corporation Peshawar (MCP) has initiated many programs for the proper collection, sorting and final disposal of MSW. Jha *et al.,* 2011 reported that in the developing countries the collection points are mostly open and unattended for many days with poor collection efficiency even less than 50%. The open and unattended collection points spread various diseases through stray animals and vectors that pass the contaminations to human food chain via their meat and milk (Jha *et al.,* 2011). In addition,

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there are also the lack of proper planning, regulation and law enforcement regarding waste treatment (Table 3). To overcome the issue, the proper planning of daily waste collection and spraying of various disinfectants are highly required. Moreover, the proper segregation such as sorting of recyclables and compostable waste with covered compartments should be adopt at the collection points (Jha *et al.,* 2011; Waqas *et al.,* 2019). As the major portion are comprised of bio-degradable fraction hence the early removal and collection of such refuse from the collection points are urgently required to reduce their environmental consequences (Table 1) (IPCC, 2010).

**Table 3** Waste management strategies in different countries (IPCC, 2006)

| Factors of MSWM | Countries | | |
|---|---|---|---|
| | Underdeveloped | Developing | Developed |
| Waste production (kg/capita/day) | 0.3 - 0.7 | 0.5 - 1.5 | > 1.0 |
| Legislation | Lack of regulation or lack of enforcement | Poor enforcement of law | Generally well monitored |
| Planning | Lack of planning / short term planning | Short to medium term planning | Medium to long term planning |
| Waste disposal | Open dump | Open dump/ sustainable landfill | Sustainable landfill |
| Recycling | Informal | Formal+ Informal | Formal |

## 3.3 Management of MSW

Waste management covers planning, engineering, financing, administration and legal aspects of all the activities associated with the production, collection, storage, transport and final disposal in an environment friendly manner by adopting principles of conservation, energy and economy (Nizami *et al.,* 2017). The hierarchy of waste management is based on environment friendly criteria that emphases on waste minimization, reuse and recycling (Nizami *et al.,* 2014). However, in many countries most of the waste are either disposed to landfill or incinerated rather than reuse or recycling (Figure 1) (Waqas *et al.,* 2018a). In current study, the data obtained from the survey depicted that the collection efficiency of waste is about 40% and all the collected waste are openly dumped. The Hazar Khwani dumping site receives about 150 tons of waste per day. Similarly, the daily waste dumped in LandiAkhoon Ahmad and Hayatabad dumping site are 80 and 90 tons respectively. In addition, scavenging has also been majorly adopted activity by thousands of people and about 50% of recyclables are scavenged at transfer stations in the city. However,

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to obtain recyclables like metals and glass the most dangerous practice by the scavengers is the open burning of waste that cause several environmental problems. On other side the remaining uncollected waste are remain in the streets or open sites. Such conditions are also particularly concerned with other low income countries where the population growth and waste production are the main challenges (Allesch and Brunner, 2014). In contrast, there are well equipped management strategies and well-surveyed mass and material flow data regarding MSW generation in the developed countries which is unavailable in the developing countries (Table 4).

**Table 4** Waste production and treatment in different EU member states (Eurostat, 2014)

| Country | Waste production (Kg per capita) | Waste treatment (%) | | |
|---|---|---|---|---|
| | | Composting and Recycling | Landfilling | Incineration |
| United Kingdom | 472 | 46 | 37 | 17 |
| Hungary | 402 | 26 | 65 | 9 |
| Austria | 552 | 62 | 3 | 35 |
| Belgium | 456 | 57 | 1 | 42 |
| Denmark | 668 | 45 | 3 | 52 |
| Ireland | 570 | 45 | 39 | 16 |
| Italy | 529 | 38 | 41 | 20 |
| Poland | 314 | 25 | 74 | 1 |
| France | 534 | 39 | 28 | 33 |
| Sweden | 462 | 47 | 1 | 52 |
| Finland | 506 | 34 | 33 | 34 |
| Netherlands | 551 | 50 | 2 | 49 |
| Germany | 611 | 65 | 0 | 35 |

Recently the city government has planned to build composting Plant, Refuse Derived Fuel (RDF) and Waste to Energy facility which would be a land mark for Peshawar city. However, there are still the lack of comprehensive survey of waste generation in summer, winter and rainy seasons in the city. Jha *et al.,* (2011) stated that seasonal variation data regarding MSW generation is required because of the usage of the high amount biomass burning in winter season, scattering of MSW takes place in summer whereas in rainy season most of the waste are flooded in gutters and water channels. For strategic planning various groups need to be considered for generation and management of MSW. The first group is the waste producer such as houses,

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growing population, institutions, and industries. Second group are vendors and their rag pickers as well as those people who pick/collect different types of waste from household around the city for their animals etc. The third group are comprised of municipal authorities, sorting and processing of non-degradable and degradable materials and the final treatment and disposal bodies (Jha *et al.,* 2011).

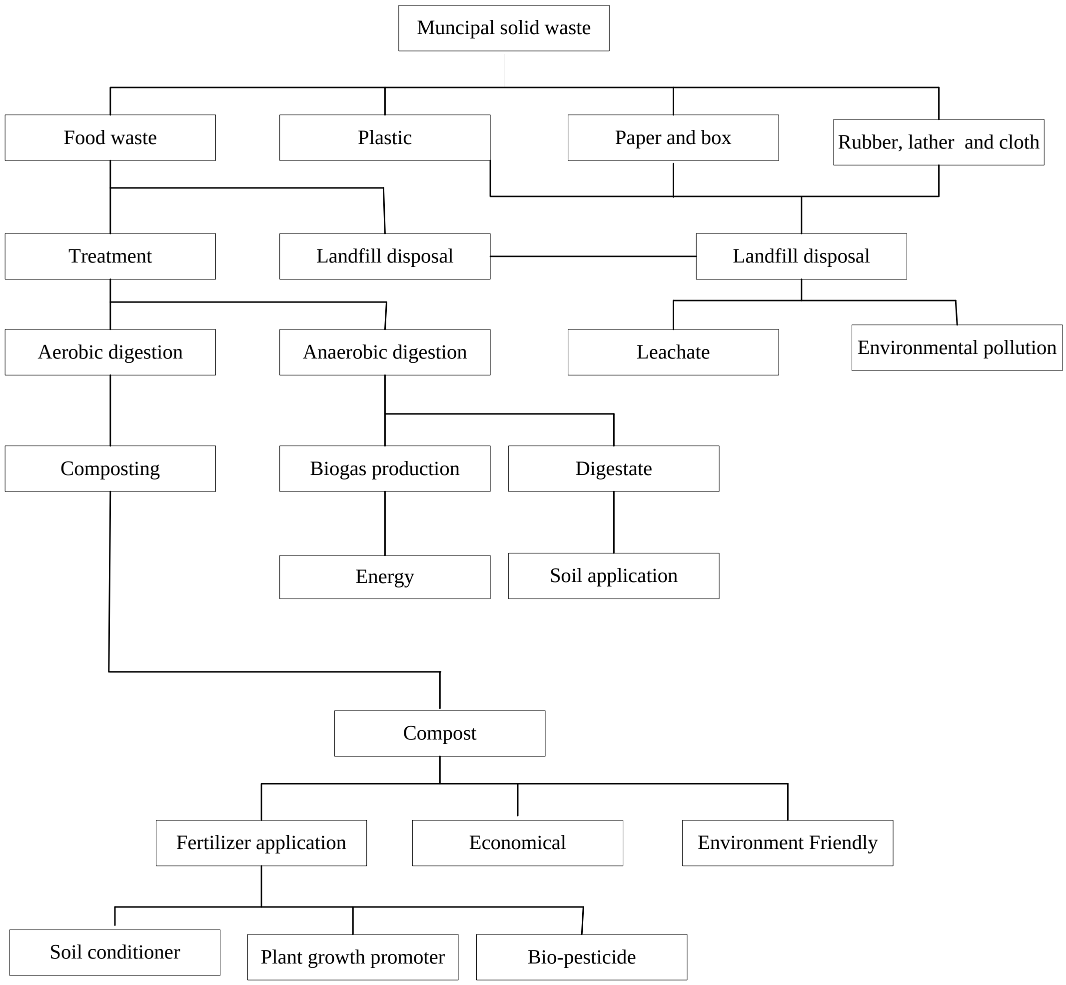


**Figure 1** Hierarchy of municipal solid waste management

## 3.4 Treatment Options of MSW Management

### 3.4.1 Composting

Composting is a biochemical process carried out under aerobic conditions in which microorganisms such as bacteria and fungi break down the complex organic matter into simpler stable humic substance (Waqas *et al.,* 2019). In the developing countries most of the MSW

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generated are comprised up to 70% of the organic waste and therefore suitable for the composting (Table 2) (Halkos and Petrou, 2016). Hence, such organic waste need to be separate at source for furthering the process (UNEP, 2016). However, many factors need to be keep under consideration for the effective composting such as adequate air supply, temperature, moisture and carbon to nitrogen ratio (Waqas *et al.,* 2018b). Similarly, there are also various technologies from simple windrow composting to highly sophisticated systems such as aerated, non-aerated static pile, in-vessel composting and vermicomposting for treating organic matters (Halkos and Petrou, 2016). This technology of waste treatment could be conomical only if the facility is at or near to the capacity (Anjum *et al.,* 2016). Moreover, it is highly required to secure sufficient waste for composting facility. The waste derived compost can be applied for land reclamation, landscaping and agriculture due to its capability to improve the physical and biological properties of the soil under variant environmental conditions (Figure 1) (UNEP, 2016).

### 3.4.2 Mechanical Biological Treatment (MBT)

Mechanical biological treatment (MBT) is the optimized process of recovering materials from the waste resource for various purposes (Eunomia, 2015). This treatment process involves both biological and mechanical treatment (Defra, 2013). The benefits of MBT are comprised of low space requirement with the recovery of energy and valuable materials (Halkos and Petrou, 2016). This process is comprised of two ideas; 1) the waste are separated and then treated and 2) the waste are treated and then separated (Defra, 2013). During this process, the organic fraction of the waste are stabilized in an aerobic biological unit to reduce its biodegradability and therefore increase its ability to produce the methane ($CH_4$) (Halkos and Petrou, 2016). After that the anaerobic biological unit convert the stabilized organic portion of MSW to $CH_4$ (UNEP, 2016). Though the recyclables from the various MBT process are of lower quality with lower market value however this process positively contribute to increase the waste recycling process. Likewise, the mechanically separated organics during processing can be used to produce compost (Halkos and Petrou, 2016). In addition, various materials for energy recovery can be recovered during waste sorting such as plastics, paper and cards that can be used for the production of Refuse Derived Fuel (RDF).

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### 3.4.3 Anaerobic Digestion (AD)

Anaerobic digestion (AD) is the process of the bacterial degradation of organic biomass under anaerobic conditions to produce $CH_4$ and digestate (Figure 1) (Eunomia, 2015). The two main types of AD are mesophilic and thermophilic AD (Anjum *et al.,* 2017). The primary difference between both types is the temperatures used in the process (Anjum *et al.,* 2017). The mesophilic AD process carried out at 35 to 40 $^oC$ whereas during thermophilic processes the temperatures reaches up to 60 $^oC$ (WRAP, 2016). As compared to other waste treatment technologies such as composting, AD is considered as the flexible method since it treat different types of waste ranging from clean organics to grey waste and highly wet 60 to 90% moisture content to dry waste (Halkos and Petrou, 2016). Therefore, kitchen and other types of waste with high moisture content could be an excellent feedstock for this technology (Anjum *et al.,* 2017). This process provide a source of renewable energy because the organic waste are broken down to produce $CH_4$ and carbon dioxide that can be used to produce energy. Different uses of the produced biogas includes; energy production, power provision to an on-site equipment and energy exported to the National Grid. Similarly, the other by-product of this process is the digestate which is a rich source of various nutrients and essential elements for soil fertility and plant growth and can be used as a source of bio-fertilizer (Figure 1) (WRAP, 2016).

### 3.4.4 Incineration

Incineration is the thermal treatment of waste biomass for energy recover (Gao *et al.,* 2017). This process reduce the waste from 90 to 95% depending on biomass composition and degree of recovery. This process reduce the amount of waste to high extend to be disposed to landfill (Mian *et al.,* 2017). This mean that incineration process did not replace the need of landfilling (Halkos and Petrou, 2016). Due to such reasons this process of waste treatment is under controversy with different opinions that either it should be used or not (Figure 2). There are various thoughts against and favor of incineration such as;

- Energy can be produce from incineration process that could be a substitute other energy plants.
- The ash produce as a result of incineration could be recycled as well as could be landfilled and is non-injurious.

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 3, Number 1, page 47 - 66, October 2019
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- Various toxic waste such as sewage and hospital waste can be successfully treated (Figure 2) (WMR, 2009).

  Similarly, the argument against incineration are;
- The products after incineration are extremely toxic and require proper disposing and hence require specific locations for dumping.
- An increase concern about different toxic emissions such as dioxins and furans.
- Heavy metals are produced as a result of incineration that are highly toxic even in minute amount (Figure 2) (WMR, 2009).

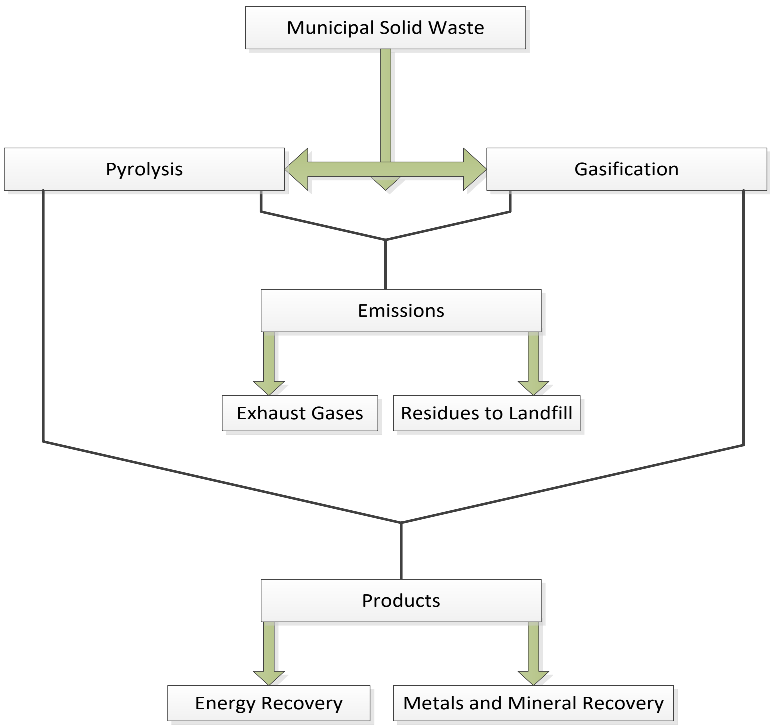


**Figure 2** Schematic representation of the benefits and limitations of incineration

There are new technologies related to incineration comprised of gasification and pyrolysis of waste materials.

### 3.4.4.1 Pyrolysis and Gasification

Both pyrolysis and gasification are relatively new technologies for treating waste but still remain legitimately unproven in many countries (Eunomia, 2015). During pyrolysis the waste especially

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organic waste is heated in oxygen deficient condition to produce different gases and liquid fuels along with solid residues mainly carbon (Defra, 2013). However, as compared to incinerators the scale of pyrolysis is smaller because the same scale pyrolysis facility would cost much higher (Miandad *et al.,* 2016). Likewise, the process of gasification is considered between combustion and pyrolysis because it requires partial air supply for the oxidation of the material. During gasification the carbon based wastes are heated in aerobic conditions to produce gas and a solid low in carbon from coal (Hinchliffe *et al.,* 2017). The addition of a gasification agent such as air assist in degradation of remaining carbon share in the pyrolysis coke at temperature 800 to 1000 °C (Bajic *et al.,* 2015). All the three process i.e., incineration, pyrolysis and gasification are the thermal treatment technologies but only differ in the levels of air supply.

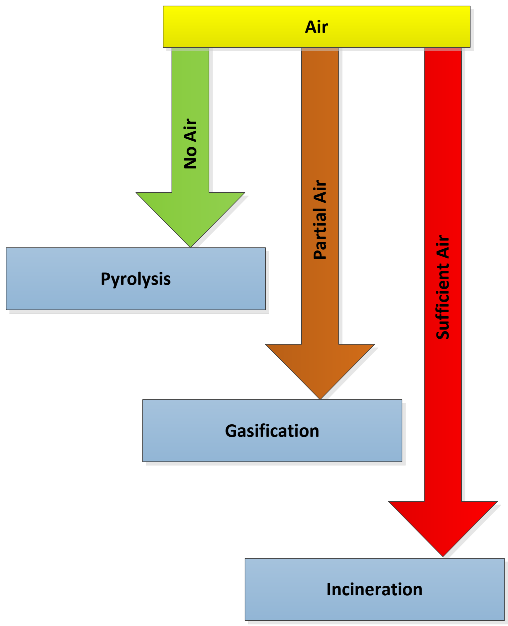


**Figure 3** Level of oxygen (air) supply during pyrolysis, gasification and incineration of MSW

### 3.4.5 Recycling

The process of recycling refers to the collection, processing and reuse of materials such as glass, wood, paper, aluminum and iron products (Halkos, 2013). There are many benefits of waste recycling including; 1) reduce the pressure on landfills and incinerators, 2) reduce the pollution by reducing the collection of new raw materials, 3) conserve natural resources such as water,

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minerals and wood, 4) save energy and sustain the environment (EPA, 2016). Recycling technology has a strong correlation with declining the landfilling because the countries with higher rates of material recycling significantly decline the rates of landfilling (Halkos and Petrou, 2016). That is the reason that the waste management strategies in most of European countries moved towards integrated waste management which is the combination of material recycling along with MBT and incineration in most of the cases (European Environmental Agency, 2015). However, in the developing and low income countries the technology of waste recycling is still in infancy and need proper planning and formulation.

### 3.4.6 Landfilling

Landfilling is one of the easiest and highly adopted procedure for treating waste (Nizami *et al.*, 2017). However, this process of waste handling is considered as inappropriate due to its hazardous effects towards human and environmental health (Figure 1). An engineered landfill comprised of a linear system of waste collection, management, collection of leachate and gas and proper covering after the completion of waste deposition (Laner *et al.,* 2012). Containment involves landfill operation and handling in such a way to enhance the waste decomposition so that the landfill gas and leachate are produced at the beginning to collect. Among the produce gases, $CH_4$ is one of the main output of the landfill which is produced as a result of organic waste decomposition under anaerobic conditions (Hinchliffe, *et al.,* 2017). The collected gas from the landfill operation can be either used in natural gas grid or can be in the gas engine for the production of heat or electricity (UNEP, 2015). There exist several techniques to pre-treat the waste before landfill disposal. The common technique for waste pre-treatment prior to landfill disposal is the MBT that will led to the materials relatively harmless with no potent to produce toxic gases and leachate (Eunomia, 2015). However, the most critical point related to landfill is the proper management which comprised of regular emission monitoring (gases and leachate), receiving system such as surface and ground water, air and soil, maintenance of proper waste covering and collection system of gas and leachate and proper legislation that will specify the period of aftercare (Laner *et al.,* 2012).

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### 3.5 Steps for Sustainable MSW management

The basic requirements for the sustainable management of MSW involves understanding the waste streams, material flow and balance along with the appropriate knowledge and willingness of the stakeholders (Jha *et al.,* 2011). The important steps that need to incorporate in formulating the strategy for MSW are discussed below.

#### 3.5.1 Identifying the Characterization of Waste Stream

Identifying the characterization of waste stream could help in formulating the strategy of waste reduction and recycling, waste to energy plan, volume reduction, composting and elemental flow (Nizami *et al.,* 2014). However, due to poor management practices the physiochemical characteristics of the waste at the site of production, transport station and final disposal sites could be change from one another (IPCC, 2010). In addition, the material balance is also required that will identify where the materials get separated from the main waste stream. Though, as compare to LCA the material balance is small option but can point out the gaps in various steps.

#### 3.5.2 Life Cycle Assessment

Life cycle assessment (LCA) is a basic process to assess the environmental consequences related to the process and their product (Bakas *et al.,* 2018). This process identify and quantify the materials and energy used and the waste released to the environment along with the implementations to mitigate the problems and improve the environment. LCA cover complete "cradle to grave" impacts of a product and comprised of four (04) different phases including 1) definition and scope of the goal, 2) inventory of the energy and materials used in all stages of the product as well as inventory of the environmental problems over the product life, 3) Impact assessment to assess the actual and potential harmful effects as a result of uses of different resources and their environmental release and 4) Assessment need to bring environmental improvement in the process and/or product. LCA could assist the decision makers in formulating the waste management strategy (Yay, 2015). Moreover, LCA methodology will define the activities of waste management as a generic operation unit independent of the specific characteristics of the processed waste along with the material flow and balance of the specific

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 3, Number 1, page 47 - 66, October 2019
*Accredited SINTA 2 by Ministry of Research, Technology, and Higher Education of The Republic of Indonesia No. 23/E/KPT/2019 on August 8th, 2019 from October 1st, 2018 to September 30th, 2023*

system to identify their impacts. In addition, LCA can also help in identifying the possible option of minimizing the waste and material recovery in different types of waste (Bakas *et al.,* 2018).

### 3.5.3 Skills Development

Skill development is educating different stakeholders with skills, research and awareness regarding any challenge in the target site (Jha *et al.,* 2011). The necessary sectors that are pre-requisite to educate are municipal authorities, educational institutes, corporate bodies and administration and nongovernment organizations (NGO). Both the administration and government should pay attention towards sustainable landfilling, educating regarding polluters pay principle and waste reduction (Nizami *et al.,* 2017). Likewise, corporate bodies may also contribute in the advancement of MSW management strategy, waste to energy plan and waste recycling (Nizami *et al.,* 2014; Spoann *et al.,* 2018). Moreover, the involvement of private sector could also contribute better services in efficient operation and maintenance for sustainable waste management beyond the collection, transport and disposal contracts. Similarly for knowledge sharing, awareness, pollution prevention and waste management options, the educational institutes and NGOs should be involved along with review functioning and quality improvement (Jha *et al.,* 2011). In addition to all these, techno-economic feasibility should be done to assess the impact of waste disposal and to provide options to decision makers for the implementation of sustainable waste management program (Nizami *et al.,* 2017).

### 3.5.4 Identification and Incorporation the Problems

There exist a gap among the administrative perception and existing conditions regarding waste production. The fact behind is most of the waste data are old which is increasing due to increasing urbanization, changing lifestyle of people and waste composition (Da Zhu *et al.,* 2008). However, most of the problems regarding waste management has been fixed but still there are various factors such as low manpower, funds and adequate treatment options reduce the efficiency sustainable waste management program (Li *et al.,* 2015). For sustaining better management practices the actual waste disposal cost should be implemented in the complete landfill budget (Li *et al.,* 2015; Hinchliffe *et al.,* 2017). Furthermore, in the management strategy the important factors should be identify and incorporate for filling the existing gap.

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 3, Number 1, page 47 - 66, October 2019
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### 3.6 Aspects for Assessing the Waste Management System

There are various aspects for the assessment of MSW management system in term of their sustainability. These aspects include economic, social and environmental aspects however instead of all these sometime only one or two aspects are considered depending on objectives of the project (Allesch and Brunner, 2014).

#### 3.6.1 Economic Aspects

For any waste management system the economic aspects are considered as the most important factor because finance in combination to the adopted technology contribute to the process efficiency and failure. Economic aspect are important and considered on both micro (business) and macro (public) level (Spoann *et al.,* 2018). In micro level the operational and investment cost are usually evaluated whereas at macro level the costs for waste management of a country or a region are calculated and evaluated either as the total costs of MSW management system or as percentage of gross domestic product (Allesch and Brunner, 2014).

#### 3.6.2 Social Aspects

This aspect cover three different perspectives including 1) social acceptability that the MSW management system must be acceptable, 2) social equity means that benefits of the waste management system must be shared equally among the citizens and 3) social function that refer to the social benefit of the management systems. Social aspect is also related to the education systems, governance, employment market and security. Moreover, there are also other key factors such as public health and safety of the society that has a close link to the environment and economy (Allesch and Brunner, 2014).

#### 3.6.3 Environmental Aspects

The most important factor that is considered to assess the impact on water, air, soil and natural resources by any waste management system (Waqas *et al.,* 2019). Furthermore, the environmental aspects are also necessary to protect the human and biodiversity from the consequences of the management processes (Nizami *et al.,* 2017). Environmental impacts are

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usually assessed by LCA methodology by examining several categories such as human toxicity, global warming potential, aquatic eutrophication, ozone depletion, ecotoxicity and acidification.

## 4. CONCLUSION

In the developing countries there are numerous problems in the management of MSW such as lower collection efficiency, awareness and knowledge regarding waste reduction and MSW management. Due to the lack of proper legislation all the waste are openly dumped that result in several public health and environmental consequences. There are several treatment options for the sustainable management of MSW including composting, incineration, gasification, pyrolysis, biological treatment and recycling. However, for each technology there are several important steps that need to incorporate in formulating the strategy for MSW such as waste stream characterization, LCA study for each management strategy, capacity building to educate the stakeholders with skills and research and identification and incorporation the gap between the problem areas. Similarly, suitability of each MSW management plan should be assess in term of economic perspectives both at micro and macro-level, social acceptability and environmental aspects to protect the environment and human from the consequences of the management processes.

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